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<p>(54) Title: FREE-MACHINING AUSTENITIC STAINLESS STEEL</p> <p>(57) Abstract</p> <p>An austenitic stainless steel alloy has a unique combination of machinability and hot workability. The alloy contains, in weight percent, about C 0.030 max., Mn 1.0–2.0, Si 1.0 max., P 0.20 max., S 0.15–0.50, Cr 17.0–19.0, Ni 8.5–11.0, Mo 1.0 max., Cu 2.5–4.0, N 0.030 max., Se 0.15 max; with the balance essentially iron.</p>			

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## Free-Machining Austenitic Stainless Steel

### Field of the Invention

The present invention relates to an austenitic stainless steel alloy and in particular, to a resulfurized austenitic stainless steel alloy and an article made therefrom, having a unique combination of machinability, hot workability, and corrosion resistance.

### Background of the Invention

Stainless steels are generally more difficult to machine than carbon and low-alloy steels because stainless steels have higher work-hardening rates compared to the carbon and low alloy steels. Consequently, it is necessary to use higher powered machines and lower machining speeds when machining the known stainless steels than when machining carbon and low-alloy steels. In addition, the useful life of the machining tool is often shortened when working with the known stainless steels.

In order to overcome the difficulties in machining the known stainless steels, some grades of stainless steels have been modified by the addition of elements such as sulfur, selenium, phosphorus, or lead. For example, AISI Type 303 stainless steel is a resulfurized, austenitic stainless steel having the following composition in weight percent:

	<u>wt. %</u>
C	0.15 max.
Mn	2.00 max.
Si	1.00 max.
P	0.20 max.
S	0.15 min
Cr	17.0 - 19.0
Ni	8.0 - 10.0
Fe	Balance

Type 303 stainless steel is known to be useful for applications which require good machinability and non-magnetic behavior, in combination with good corrosion resistance.

Some grades of Type 303 stainless steel have included copper. However, such alloys have proven difficult to hot work. Since sulfur is also known to adversely affect hot workability in an austenitic stainless steel, the problem is compounded when both copper and sulfur are used.

In view of the state of the art as outlined above, it would be highly desirable to have an austenitic stainless steel that provides a better combination of machinability and hot workability than is presently provided by the known, copper-containing, austenitic stainless steels.

### Summary of the Invention

The problems associated with the known copper-containing austenitic stainless steel alloys are solved to a large degree by an alloy in accordance with the present invention. The alloy according to the present invention is an austenitic stainless steel alloy that provides improved machinability compared to AISI Type 303 alloy, while also providing good hot workability.

The broad, intermediate, and preferred compositional ranges of the austenitic stainless steel of the present invention are as follows, in weight percent:

	<u>Broad</u>	<u>Intermediate</u>	<u>Preferred A</u>	<u>Preferred B</u>
C	0.030 max.	0.025 max.	0.020 max.	0.015 max.
Mn	1.0 - 2.0	1.5 - 2.0	1.5 - 2.0	1.75 - 2.0
Si	1.0 max.	0.75 max.	0.50 max.	0.50 max.
P	0.20 max.	0.10 max.	0.05 max.	0.05 max.
S	0.15-0.50	0.20 - 0.40	0.25 - 0.40	0.30 - 0.40
Cr	17.0 - 19.0	17.0 - 18.5	17.0 - 18.0	17.0 - 17.5
Ni	8.5 - 11.0	9.0 - 10.5	9.5 - 10.0	9.7 - 10.0
Mo	1.0 max.	0.75 max.	0.75 max.	0.75 max.
Cu	2.5-4.0	2.7-3.5	3.0-3.5	3.0 - 3.5
N	0.030 max.	0.025 max.	0.020 max.	0.015 max.
Se	0.15 max.	0.10 max.	0.05 max.	0.05 max.

The balance of the alloy is essentially iron except for the usual impurities found in commercial grades of such steels and minor amounts of additional elements which may vary from a few thousandths of a percent up to larger amounts that do not objectionably detract from the desired combination of properties provided by this alloy.

The foregoing tabulation is provided as a convenient summary and is not intended thereby to restrict the lower and upper values of the ranges of the individual elements of the alloy of this invention for use in combination with each other, or to restrict the ranges of the elements for use solely in combination with each other. Thus, one or more of the element ranges of the broad composition can be used with one or more of the other ranges for the remaining elements in the preferred composition. In addition, a minimum or maximum for an element of one preferred embodiment can be used with the maximum or minimum for that element from another preferred embodiment. Throughout this application, percent or the symbol % means percent by weight, unless otherwise indicated.

### Detailed Description

In the alloy according to the present invention, carbon and nitrogen are each restricted to not more than about 0.030%, better yet to not more than about 0.025%, and preferably to not more than about 0.020% in order to benefit the machinability of this alloy. The best results are obtained when carbon and nitrogen are each restricted to not more than about 0.015 %. However, the low amounts of carbon and nitrogen used in this alloy result in reduced stability of the austenitic microstructure and increased magnetic permeability when the alloy is cold worked.

Nickel is present in this alloy at least partly to offset the adverse effect on the stability of the austenite that results from the restricted amounts of carbon and nitrogen present in the alloy. Nickel is also present in the alloy because it reduces

ferrite, benefits the corrosion resistance, reduces the work hardening rate, and contributes to the improved machinability provided by this alloy. To achieve those objectives, at least about 8.5%, better yet at least about 9.0%, and preferably at least about 9.5% nickel is present in this alloy. When very low  
5 levels of carbon and nitrogen are present (e.g., 0.02% or less) the alloy preferably contains at least about 9.7% nickel. Too much nickel adversely affects the hot workability of the alloy. Moreover, the benefits realized from larger amounts of nickel are not commensurate in scope with the additional cost of including such amounts of that element in the alloy. Accordingly, the presence of nickel in this  
10 alloy is restricted to not more than about 11.0%, better yet to not more than about 10.5%, and preferably to not more than about 10.0%.

At least about 2.5%, better yet at least about 2.7% or 2.75%, and preferably at least about 3.0% copper is present in the alloy because it benefits the machinability of this alloy over and above the benefit provided by reducing  
15 carbon and nitrogen and increasing nickel. The improved machinability that results from the presence of at least 2.5% copper in this alloy is particularly evident in form tool machining. Copper also stabilizes the austenite and inhibits the amount of ferrite in this alloy. Furthermore, copper benefits the corrosion resistance and reduces the work hardening rate of the alloy. Like nickel, too  
20 much copper adversely affects the hot workability of this alloy. Therefore, the amount of copper present in the alloy is restricted to not more than about 4.0% and preferably to not more than about 3.5%.

At least about 0.15%, better yet at least about 0.20%, and preferably at least about 0.25% sulfur is present in this alloy because of sulfur's beneficial  
25 effect on machinability. For optimum free-machining characteristics, at least about 0.30% sulfur can be present in this alloy. The sulfur content is preferably restricted to not more than about 0.50% and preferably to not more than about 0.40% because too much sulfur adversely affects the corrosion resistance and the hot and cold workability of this alloy. Selenium also benefits machinability and

is particularly useful when the alloy is to be cold formed. Therefore, when desired, up to about 0.15% selenium can be present in this alloy in place of some or all of the sulfur on a weight percent basis. When present, selenium is preferably restricted to not more than about 0.10% and better yet to not more than 5 0.05%.

At least about 1.0%, better yet at least about 1.5%, and preferably at least about 1.75% manganese is present in this alloy to promote the formation of manganese-rich sulfides which benefit machinability. Manganese is preferably restricted to not more than about 2.0% in this alloy because too much manganese 10 adversely affects the corrosion resistance of the alloy.

Chromium contributes to the alloy's resistance to general corrosion and for that reason, at least about 17.0% chromium is present in this alloy. Too much chromium can result in the formation of ferrite, so chromium is restricted to not more than about 19.0%, better yet to not more than about 18.5%, and preferably 15 to not more than about 18.0%. For best results the alloy contains not more than about 17.5% chromium.

The alloy according to this invention may also contain the following elements. Up to about 1.0% silicon can be present in the alloy from deoxidizing additions during melting. Silicon is preferably limited to not more than about 20 0.75%, and better yet to not more than about 0.50% because of its strong effect on promoting ferrite formation, particularly with the very low carbon and nitrogen present in this alloy. Up to about 1.0% molybdenum can be present in this alloy to enhance the corrosion resistance provided by the alloy, particularly in chloride-containing environments. However, molybdenum is preferably limited 25 to not more than about 0.75% because it too promotes the formation of ferrite.

Up to about 0.2% phosphorus can be present in the alloy to improve the quality of the surface finish of parts machined from this alloy. Preferably, phosphorus is limited to not more than about 0.1%, and better yet to not more than about 0.05%, because too much phosphorus causes embrittlement and

adversely affects the machinability of this alloy as measured by machine tool life. Up to about 0.01% calcium can be present in this alloy to promote formation of calcium-aluminum-silicates which benefit the alloy's machinability with carbide cutting tools. A small but effective amount of boron, about 0.0005 - 0.01%, can  
5 also be present in this alloy for its beneficial effect on hot workability.

The balance of the alloy is essentially iron and the usual impurities found in similar grades of austenitic stainless steels.

No special techniques are required in melting, casting, or working the alloy of the present invention. Arc melting followed by argon-oxygen  
10 decarburization (AOD) is the preferred method of melting and refining, but other practices can be used. This alloy can be made using powder metallurgy techniques, if desired. The alloy is also suitable for continuous casting processes.

The alloy of the present invention is formed into a variety of shapes for a wide variety of uses and lends itself to the formation of billets, bars, rod, wire,  
15 strip, plate, or sheet using conventional practices. The alloy of the present invention, and articles made therefrom, are useful in a wide range of applications. Because of its superior machinability, the alloy is useful for making parts and components that require machining to obtain their final shape, especially using  
automated machining equipment.

20

### Working Examples

In order to demonstrate the improved form tool machinability provided by the alloy of the present invention, Examples 1 to 6 having the compositions in weight percent shown in Table 1 were prepared. For comparison purposes, Heats  
25 A-E with compositions outside the range of the present invention were also prepared. Their weight percent compositions are also included in Table 1.



**Table 1**

Ex./Ht.											
	No.	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	N
5	1	.022	1.85	.39	.034	.36	17.22	9.75	.50	2.75	.021
	2	.022	1.84	.38	.035	.20	17.20	9.70	.50	2.70	.023
	3	.024	1.03	.57	.037	.43	18.13	10.90	.35	2.56	.014
	4	.023	1.53	.58	.040	.42	18.04	10.91	.35	2.55	.013
	5	.019	1.53	.57	.040	.43	18.08	10.90	.35	2.79	.013
10	6	.020	1.76	.55	.033	.43	18.24	10.87	.35	3.02	.013
	A	.070	1.86	.40	.037	.35	17.28	8.84	.50	.76	.031
	B	.022	1.85	.39	.034	.36	17.33	9.79	.50	.75	.022
	C	.022	1.84	.39	.035	.20	17.27	9.81	.50	.76	.021
	D	.070	1.86	.38	.034	.36	17.16	8.69	.50	2.73	.030
15	E	.022	0.60	.56	.038	.43	18.17	10.92	.35	2.28	.014

The balance of each composition is essentially iron and the usual impurities.

Heat A is representative of AISI Type 303 alloy. Heats B and C are similar to Heat A but contain significantly lower amounts of carbon and nitrogen and significantly higher nickel. Heat C contains lower sulfur than Heats A and B. Heat D is representative of a Japanese alloy referred to as SUS 303Cu. Heat E contains lower manganese and copper than the alloy according to this invention.

Examples 1 and 2 were prepared for comparison with comparative Heats A-D and Examples 3-6 were prepared for comparison with Heat E.

Examples 1-6 and the comparative Heats A-E were prepared from 400 lb. heats that were induction melted under a cover of argon gas and cast as 7.5 in. (190.5 mm) square ingots. The ingots were pressed to 4 in. (101.6 mm) square billets from a temperature of 2300°F (1260°C). The billets were ground to remove surface defects and the ends were cut off. The billets were processed to bars by cogging to 2.125 in. (53.975 mm) round, followed by hot rolling to a diameter of 0.719 in. (18.3 mm) from a temperature of 2200-2250°F (1204-1250°C) and cut to lengths of about 12 ft. (365.8 cm). The round bars were turned to a diameter of 0.668 in. (17.0 mm) to remove surface defects and pointed for cold drawing. The round bars were annealed at 1950°F (1065°C) and water

quenched. The annealed bars were cold drawn to 0.637 in. (16.2 mm), straightened, and then ground to 0.625 in. (15.9 mm).

5 To evaluate machinability, Examples 1-6 and comparative Heats A-E were tested on an automatic screw machine. A form tool was used to machine the 0.625 in. (15.9 mm) diameter bars of each composition to provide parts having a contoured surface. Examples 1 and 2 and Heats A-D were machined at a speed of 217 surface feet per minute (sfpm) and a tool feed rate of 0.002 inches per revolution (ipr). Examples 3-6 and Heat E were machined at a speed of 246 sfpm and a tool feed rate of 0.002 ipr. As a consequence of gradual wear induced  
10 on the form tool by the machining process, the diameter of the machined parts gradually increases. Unless otherwise indicated, the tests were terminated when a 0.003 in. (0.076 mm) increase in the small diameter of the machined parts was observed. Improved machinability is demonstrated when a significantly higher number of parts is machined compared to a reference material.

15 The results of the machinability tests are shown in Table 2 as the number of parts machined (No. of Parts). Each alloy was tested in two or three separate runs. The weight percents of nickel, copper, carbon, nitrogen, and sulfur for each composition tested are included in Table 2 for convenient reference.

**Table 2**

	<u>Ex./Ht</u>	<u>Ni</u>	<u>Cu</u>	<u>C</u>	<u>N</u>	<u>S</u>	<u>No. of Parts</u>
	1	9.75	2.75	0.022	0.021	0.36	590+/630/600+
	2	9.70	2.70	0.022	0.023	0.20	600+/620+/600+
5	3	10.90	2.56	0.024	0.014	0.43	260-/330-
	4	10.91	2.55	0.023	0.013	0.42	290/290-
	5	10.90	2.79	0.019	0.013	0.43	370-/340-
	6	10.87	3.02	0.020	0.013	0.43	370-/410-
	A	8.84	0.76	0.070	0.031	0.35	250-/110-/110-
10	B	9.79	0.75	0.022	0.022	0.36	410/350/350
	C	9.81	0.76	0.022	0.021	0.20	260/310/280
	D	8.69	2.73	0.070	0.030	0.36	370-/340-/250-
	E	10.92	2.28	0.022	0.014	0.43	230/270-
15	+ indicates that the test was discontinued at the number of parts indicated.						
	- indicates that the tool failed at the number of parts indicated.						

The data in Table 2 clearly show the superior form tool machinability of Examples 1 and 2 compared to Heats A, B, C, and D. The data also show that Examples 3-6 of the alloy according to this invention provide superior form tool machinability compared to Heat E.

To demonstrate the superior hot workability of the alloy according to this invention compared to the known copper-containing grade of Type 303 alloy, Examples 7-12 having the compositions in weight percent shown in Table 3 were prepared. For comparison purposes Heat F with a composition that is representative of Type 303Cu and Heat G with a composition that contains lower manganese and copper than the claimed alloy were also prepared. The weight percent compositions of Heats F and G are also shown in Table 3.

**Table 3**

Ex./Ht.		C	Mn	Si	P	S	Cr	Ni	Mo	Cu	Co	N
No.												
5	7	.022	1.81	.41	.037	.20	17.34	9.79	.50	3.04	.26	.022
	8	.021	1.81	.40	.036	.33	17.36	9.76	.50	3.06	.26	.022
	9	.022	1.02	.53	.037	.44	18.22	10.84	.35	2.54	—	.014
	10	.020	1.52	.54	.037	.43	18.27	10.84	.35	2.54	—	.014
	11	.022	1.53	.55	.037	.44	18.24	10.81	.35	2.77	—	.014
10	12	.022	1.78	.54	.037	.44	18.25	10.84	.35	3.02	—	.013
	F	.067	1.82	.41	.036	.34	17.37	8.78	.50	3.05	.26	.022
	G	.024	0.58	.53	.035	.43	18.22	10.74	.35	2.23	—	.014

The balance of each composition is essentially iron and the usual impurities.

15            Examples 7-12 and Heats F and G are 30 lb. heats that were induction melted under a cover of argon gas and cast as 4 in. square ingots. Standard 0.250 in. gage-diameter specimens for hot ductility (Gleeble) testing were prepared from the ingots of each heat. The material for the test specimens was taken from both near-surface and core portions of the respective ingots.

20            The results of hot ductility testing on-heating for Examples 7 and 8, and Heat F are shown in Table 4A below including the test temperature (Test Temp.) in degrees Fahrenheit (°F), the ingot location from which the material for the test specimen was taken (Loc.), the ultimate tensile strength (U.T.S.) in ksi, and the percent reduction in area (%R.A.).

25

**Table 4A**

	<u>Ex./Ht. ID</u>	<u>Test Temp.</u>	<u>L c.</u>	<u>U.T.S.</u>	<u>%R.A.</u>
5	7	2300	S/C	11.8/11.6	61.4/50.1
	8			13.5/12.2	42.5/46.9
	F			10.8/12.1	49.9/39.8
	7	2350	S/C	12.5/10.6	64.2/43.0
	8			9.8/11.2	39.3/15.7
10	F			11.7/9.9	44.0/8.9
	7	2400	S/C	10.6/10.9	34.7/29.7
	8			10.0/9.1	27.4/11.8
	F			10.8/5.8	17.5/2.6
	7	2450	S	10.4	13.9
15	8			4.8	0
	F			6.5	0

S indicates material taken from surface region of ingot.  
C indicates material taken from core region of ingot.

The results of hot ductility testing on cooling for Examples 7 and 8 and Heat F are shown in Table 4B below including the preheat temperature (Preheat Temp.) and the test temperature (Test Temp.) in degrees Fahrenheit (°F), the ingot location from which the material for the test specimen was taken (Loc.), the ultimate tensile strength (U.T.S.) in ksi, and the percent reduction in area (%R.A.). The test specimens were preheated to 2350°F at the start of the respective tests.

**Table 4B**

	<u>Ex./Ht. ID</u>	<u>Preheat Temp.</u>	<u>Test Temp.</u>	<u>Loc.</u>	<u>U.T.S.</u>	<u>%R.A.</u>
5	7	2350	2000	S/C	15.2/15.9	41.0/43.5
	8				15.6/15.5	41.6/43.9
	F				16.6/NT	39.7/NT
10	7	2350	2100	S/S	15.9/15.1	59.5/51.0
	8				12.9/13.8	62.7/50.9
	F				14.8/15.1	47.3/48.0
15	7	2350	2200	S/S	14.4/13.9	65.3/62.4
	8				9.4/12.1	60.5/47.9
	F				13.6/11.5	50.9/48.1
20	7	2350	2300	S/S	14.1/12.7	55.9/49.4
	8				13.1/11.7	29.5/52.7
	F				12.4/11.8	40.7/51.3

S indicates material taken from near-surface region of ingot.

C indicates material taken from core of ingot.

NT indicates not tested.

20 The data in Tables 4A and 4B show that on-average, Examples 7 and 8 of the alloy according to the present invention, have better hot ductility than Heat F, an example of the known copper-containing grade of Type 303 alloy.

25 The results of hot ductility testing on-heating for Examples 9-12 and Heat G are shown in Table 4C below including the test temperature (Test Temp.) in degrees Fahrenheit (°F), the ultimate tensile strength (U.T.S.) in ksi, and the percent reduction in area (%R.A.). Material for all specimens was taken from the surface region of ingot.

**Table 4C**

	<u>Ex./Ht. ID</u>	<u>Test Temp.</u>	<u>U.T.S.</u>	<u>%R.A.</u>
5	9	2300	19.6/14.5	52.7/63.8
	10	"	17.2/16.2	57.6/59.1
	11	"	21.8/17.9	51.7/58.5
	12	"	20.5/16.8	48.8/52.3
	G	"	19.6/17.2	60.9/48.7
10	9	2400	18.9/19.9	0/0
	10	"	19.8/21.9	6.7/0
	11	"	16.2/20.8	42.7/26.7
	12	"	19.3/17.1	27.5/27.4
	G	"	20.3/17.6	0/1.2

15           The data in Table 4C show that Examples 11 and 12 of the alloy  
according to the present invention, have better hot ductility than Heat G, at the  
2400°F test temperature. The improvement in hot ductility provided by the  
examples of the alloy according to this invention was realized despite their higher  
copper content, which is generally expected to adversely affect the hot  
20   workability of an austenitic stainless steel alloy.

          The terms and expressions that have been employed herein are used as  
terms of description and not of limitation. There is no intention in the use of such  
terms and expressions to exclude any equivalents of the features described or any  
portions thereof. It is recognized, however, that various modifications are  
25   possible within the scope of the invention claimed.

What is claimed is:

1. A free-machining, austenitic, stainless steel alloy consisting essentially of, in weight percent, about

5	C	0.030 max.
	Mn	1.0 - 2.0
	Si	1.0 max.
	P	0.20 max.
	S	0.15 - 0.50
10	Cr	17.0 - 19.0
	Ni	8.5 - 11.0
	Mo	1.0 max.
	Cu	2.5 - 4.0
	N	0.030 max.
15	Se	0.15 max.

and the balance essentially iron.

2. An austenitic stainless steel alloy as set forth in Claim 1 which contains at least about 1.5% manganese.

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3. An austenitic stainless steel alloy as set forth in Claim 1 which contains at not more than about 0.025% carbon and not more than about 0.025% nitrogen.

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4. An austenitic stainless steel alloy as set forth in Claim 1 which contains at least about 2.7% copper.

5. An austenitic stainless steel alloy as set forth in Claim 1 which contains at least about 9% nickel.

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6. An austenitic stainless steel alloy as set forth in Claim 1 which contains not more than about 0.4% sulfur.

7. A free-machining, austenitic, stainless steel alloy consisting essentially of, in weight percent, about

5	C	0.025 max.
	Mn	1.5 - 2.0
	Si	0.75 max.
	P	0.10 max.
	S	0.20 - 0.40
10	Cr	17.0 - 18.5
	Ni	9.0 - 10.5
	Mo	0.75 max.
	Cu	2.7 - 3.5
	N	0.025 max.
15	Se	0.10 max.

and the balance essentially iron.

8. An austenitic stainless steel alloy as set forth in Claim 7 which contains at least about 1.75% manganese.

9. An austenitic stainless steel alloy as set forth in Claim 7 which contains not more than about 0.020% carbon and not more than about 0.020% nitrogen.

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10. An austenitic stainless steel alloy as set forth in Claim 7 which contains at least about 3% copper.

11. An austenitic stainless steel alloy as set forth in Claim 7 which contains at least about 9.5% nickel.

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12. An austenitic stainless steel alloy as set forth in Claim 7 which contains at least about 0.25% sulfur.

13. A free-machining, austenitic, stainless steel alloy consisting  
5 essentially of, in weight percent, about

	C	0.020 max.
	Mn	1.5 - 2.0
	Si	0.50 max.
	P	0.05 max.
10	S	0.25 - 0.40
	Cr	17.0 - 18.0
	Ni	9.5 - 10.0
	Mo	0.75 max.
	Cu	3.0 - 3.5
15	N	0.020 max.
	Se	0.05 max.

and the balance essentially iron.

20 14. An austenitic stainless steel alloy as set forth in Claim 13 which contains at least about 1.75% manganese.

15. An austenitic stainless steel alloy as set forth in Claim 13 which contains not more than about 0.015% carbon and not more than about 0.015%  
25 nitrogen.

16. An austenitic stainless steel alloy as set forth in Claim 13 which contains at least about 0.3% sulfur.

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17. A free-machining, austenitic, stainless steel alloy consisting essentially of, in weight percent, about

	C	0.015 max.
	Mn	1.75 - 2.0
5	Si	0.50 max.
	P	0.05 max.
	S	0.30 - 0.40
	Cr	17.0 - 17.5
	Ni	9.7 - 10.0
10	Mo	0.75 max.
	Cu	3.0 - 3.5
	N	0.015 max.
	Se	0.05 max.

15 and the balance essentially iron.

# INTERNATIONAL SEARCH REPORT

Intern. at Application No

PCT/US 00/10455

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C22C38/60 C22C38/42 C22C38/58

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C22C C21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal, WPI Data, CHEM ABS Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 736 610 A (UGINE SAVOIE SA) 9 October 1996 (1996-10-09) claims 1-6 ---	1-17
X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 11, 29 November 1996 (1996-11-29) -& JP 08 176748 A (DAIDO STEEL CO LTD), 9 July 1996 (1996-07-09) abstract ---	1-17
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

28 August 2000

Date of mailing of the international search report

04/09/2000

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# INTERNATIONAL SEARCH REPORT

Intern. al Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 215 (C-0716), 8 May 1990 (1990-05-08) -& JP 02 050937 A (DAIDO STEEL CO LTD), 20 February 1990 (1990-02-20) abstract ----	1-17
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